You Know Where the Parent Body is but Where are the Co-orbitals?

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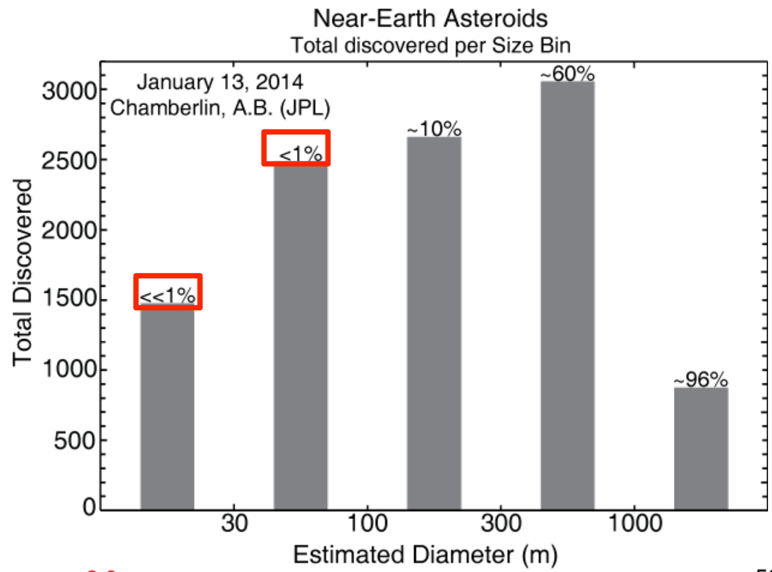
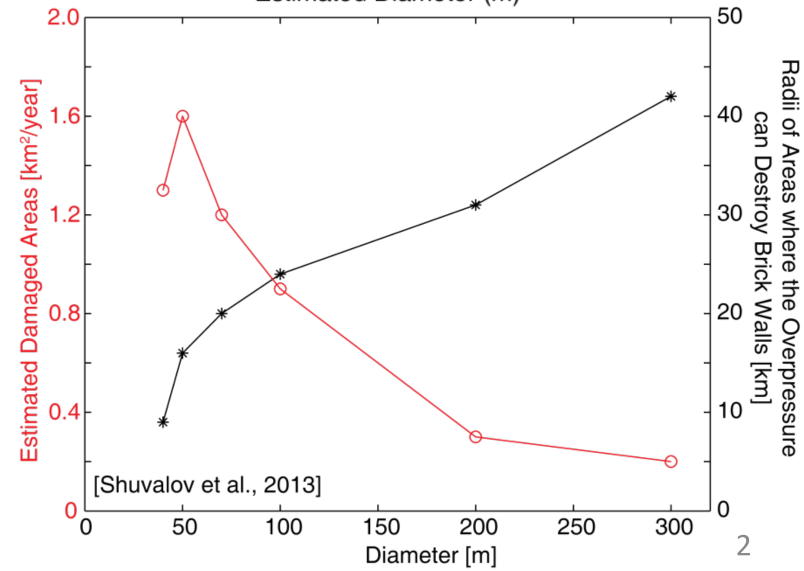
Co-orbitals : Difficult to Identify but Potentially Hazardous

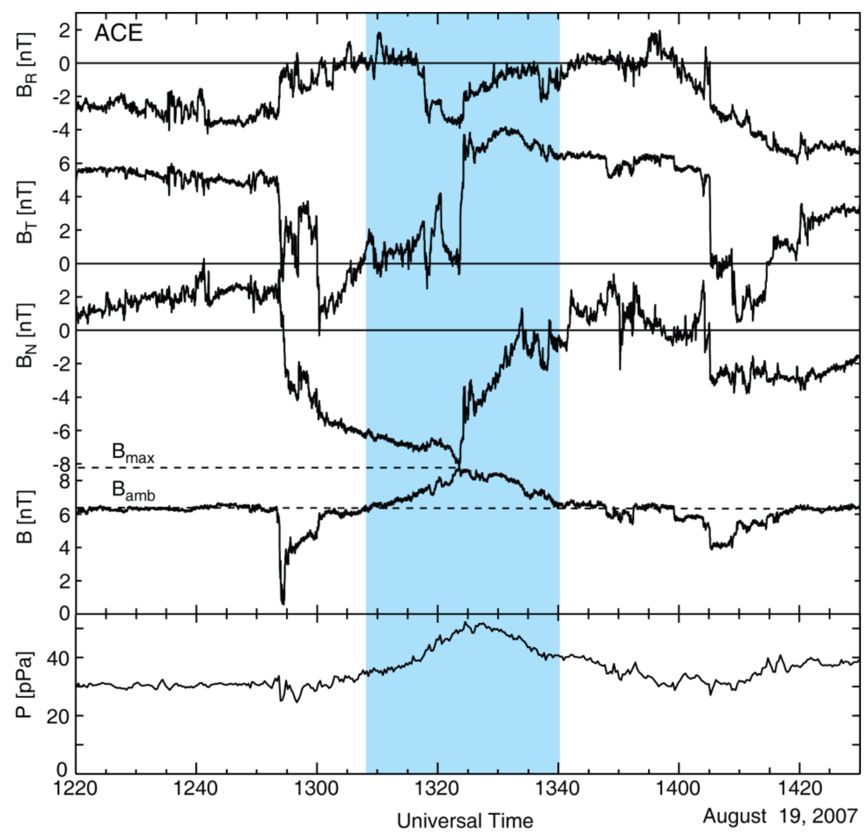
- Non-destructive collisions with large near-Earth objects (NEOs) can produce co-orbiting debris.
- If the debris is less than 100m in diameter, it is hard to detect by traditional methods.
- However, simulation results show that objects of 50m in diameter result in the most damage per year.



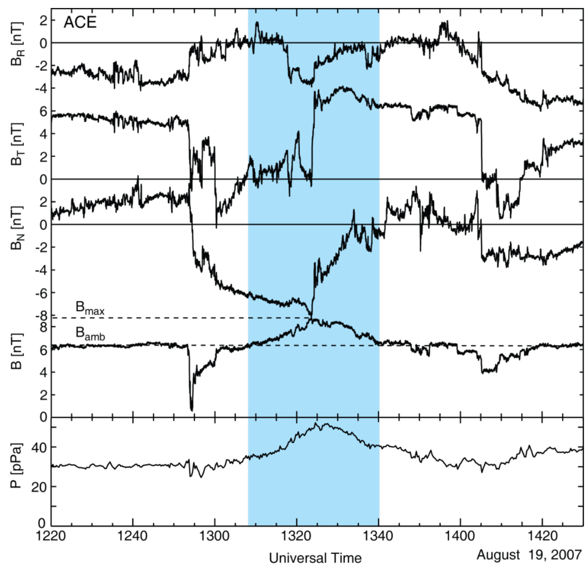


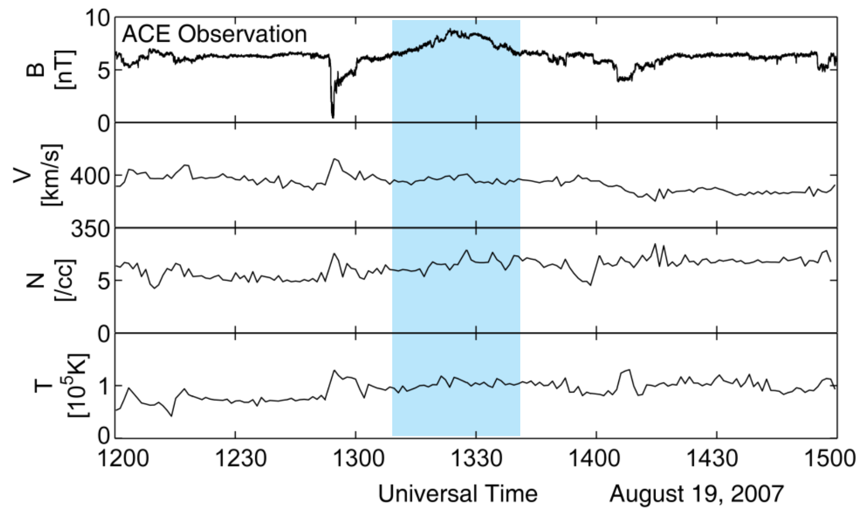
How to Monitor the Co-orbitals?

- The co-orbitals collide regularly and disruptively with small but numerous meteoroids.
- The clouds of nanoscale dust/gas released in such collisions interact with the solar wind electromagnetically and create large-scale perturbations called interplanetary field enhancements (IFEs).



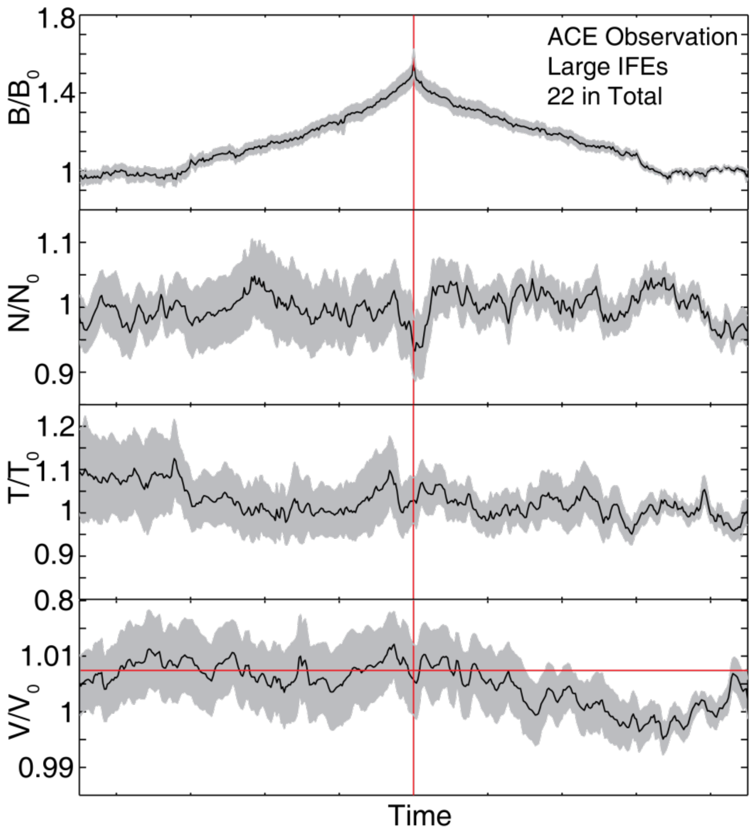
Collisional Signatures in the Solar Wind: IFEs (1)





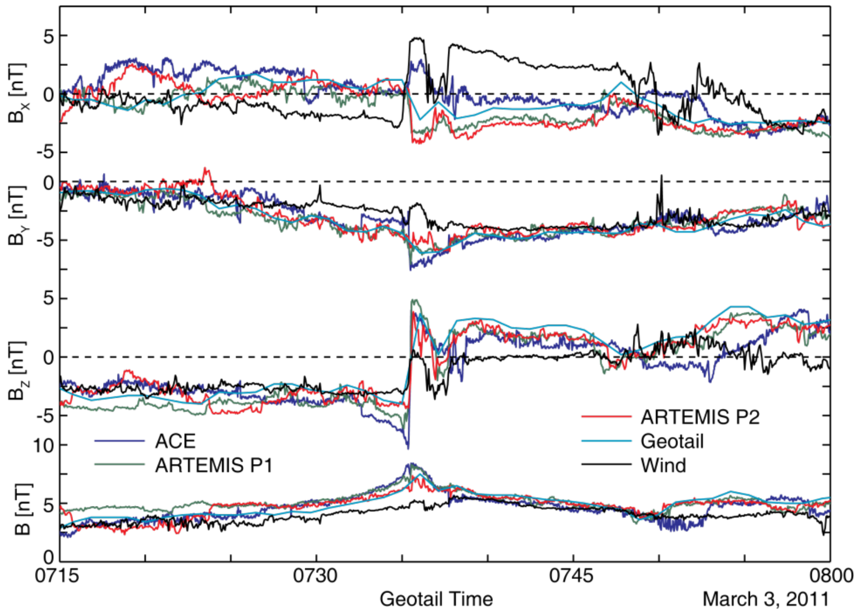
- An IFE is mainly a magnetic structure. It has enhanced field strength, bent field lines and central pressure enhancement.
- The plasma and magnetic signatures are uncorrelated, indicating that the magnetic structure was built slowly relative to the ion thermal speed.

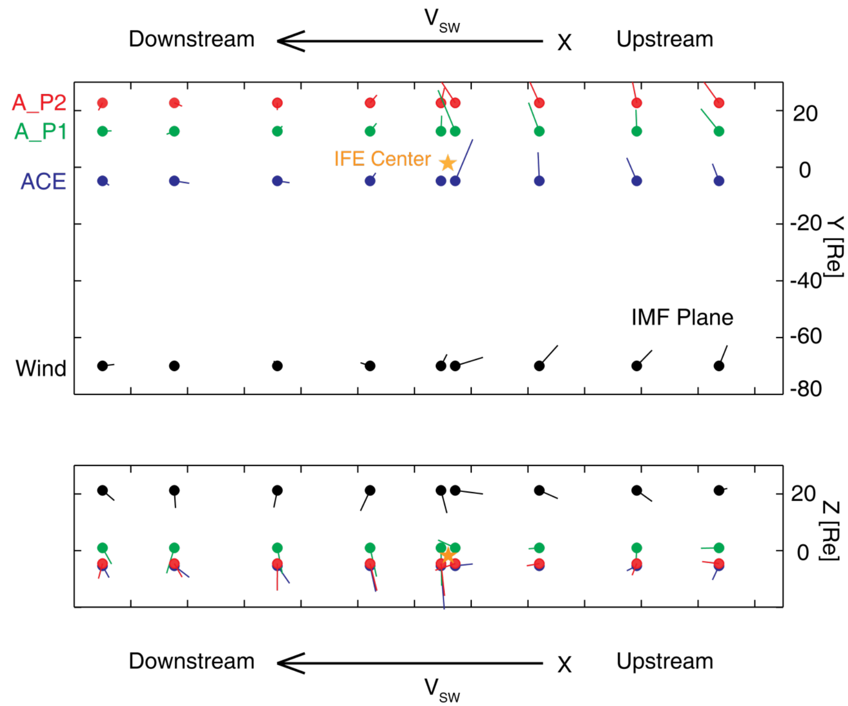
Collisional Signatures in the Solar Wind: IFEs (2)

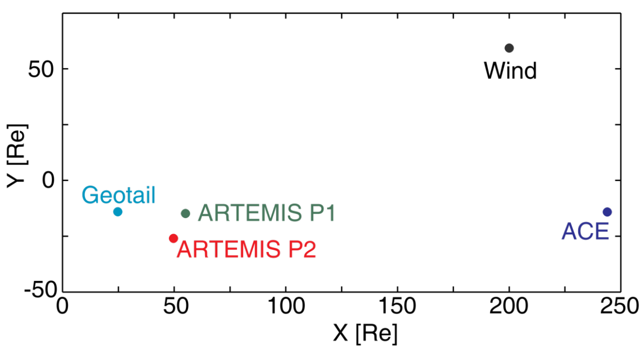


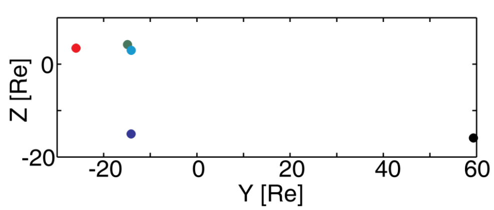
- Superposed epoch analysis shows that there is a small (about 0.5%) but statistically significant solar wind slowdown on the trailing edge.
- Momentum is extracted from the solar wind.

IFE Magnetic Field Geometry from Five Spacecraft



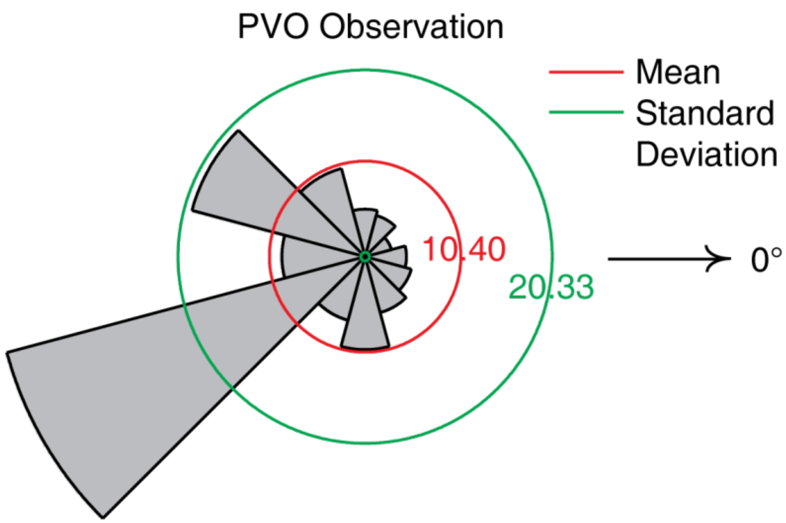


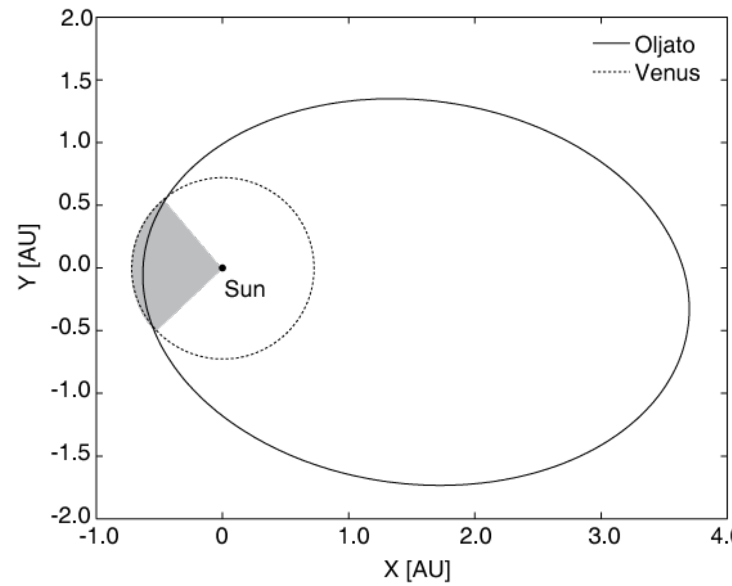




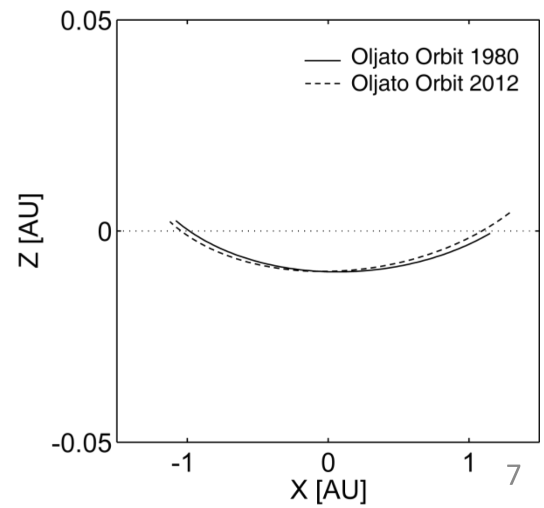
- Upstream: magnetic field is draped around the IFE, extracting momentum from the solar wind in order to push the IFE out of the Sun's gravitational well.
- Downstream: the magnetic field has been twisted in the direction of the electric field.
- Different mass to charge ratio of the dust from that of the solar wind protons?

Association between IFEs and Co-orbitals of Asteroid 2201 Oljato at 0.72AU



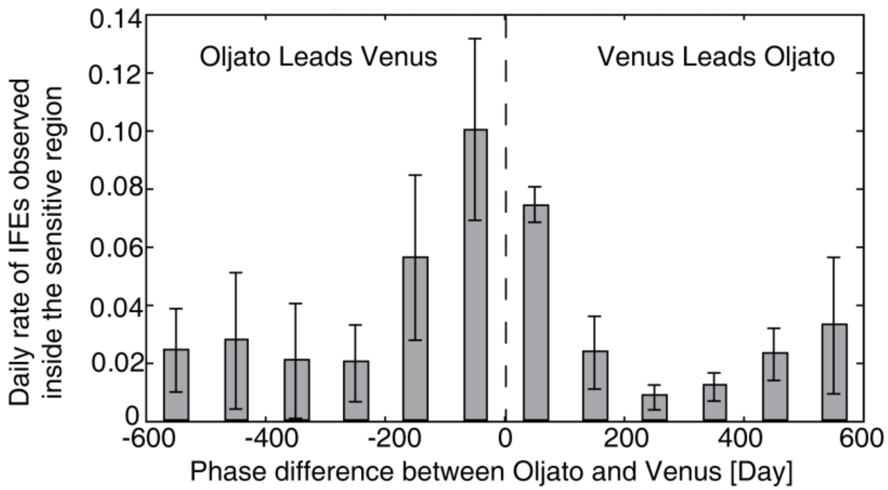


- IFEs detected by PVO clustered in the longitudinal range where orbit of asteroid 2201 Oljato was inside that of Venus.
- Oljato has a small inclination with respect to the orbital plane of Venus.
- We expect that disturbance in the sensitive region can move radially outward and be detected by spacecraft downstream.

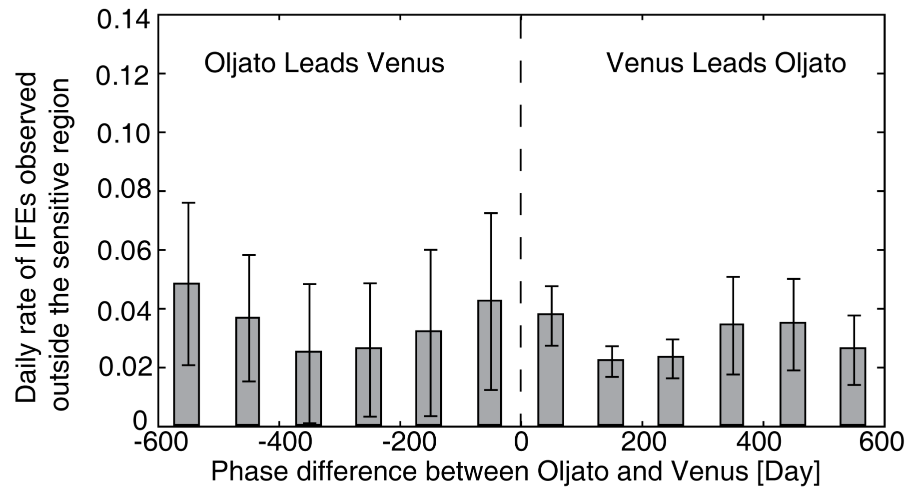


Co-orbitals of Oljato as A Source of IFEs

Inside the Sensitive Region

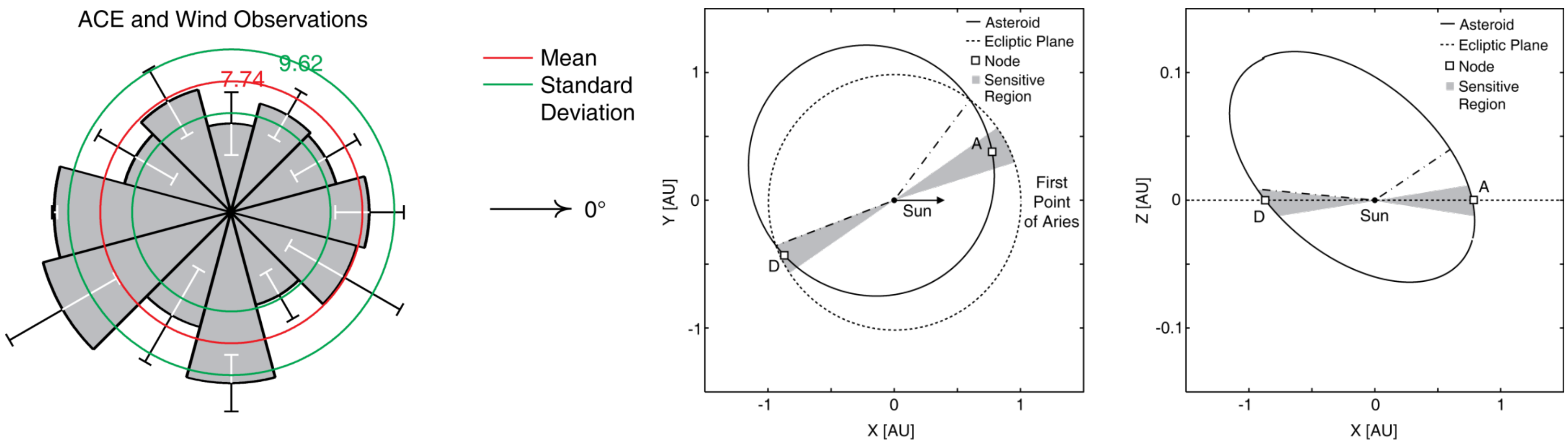


Outside the Sensitive Region



- There is a clear association between IFE occurrence and passages of Oljato inside the sensitive region.
- There is a weak correlation outside the sensitive region (spread of the co-orbitals).
- Not Oljato itself, but the co-orbiting material both leading and lagging Oljato is responsible for the IFEs.

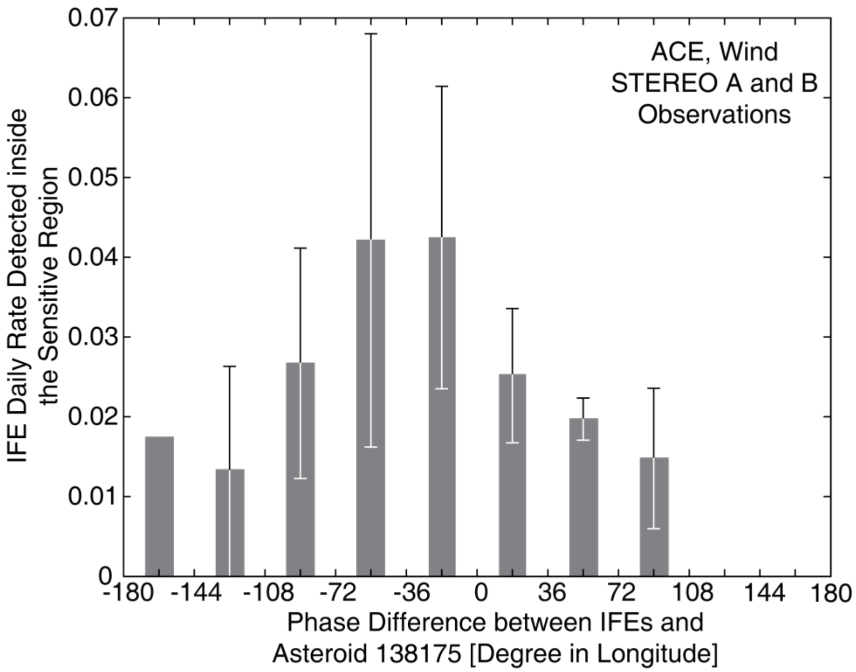
Association between IFEs and Co-orbitals of Asteroid 138175 at 1AU



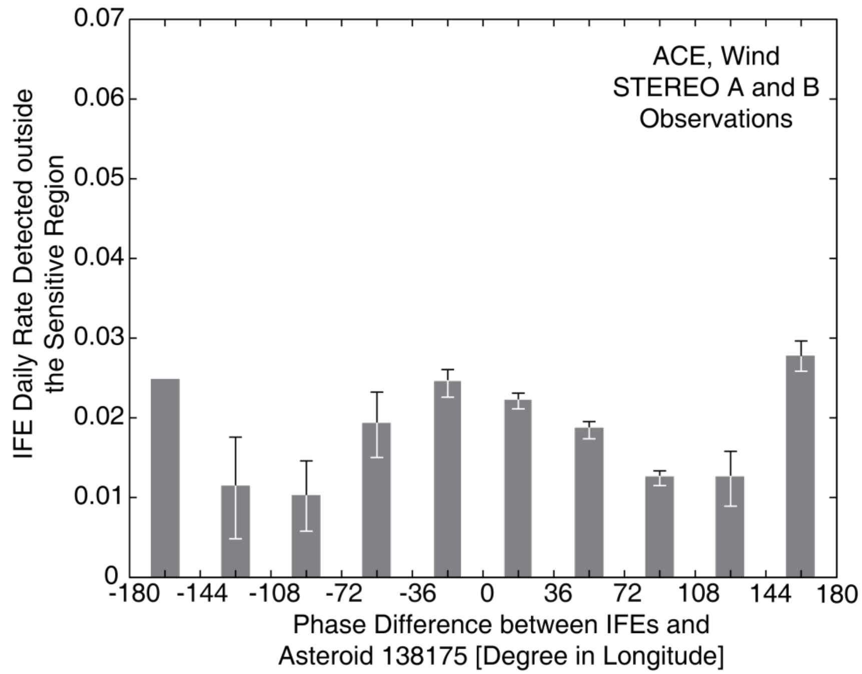
- At 1AU, IFE occurrence clusters in the longitudinal range from 195˚ to 215˚, indicating a higher collision rate, thus denser interplanetary objects, in this region.
- We compare the ecliptic-plane passages of known NEOs in this region and find that co-orbiting material of asteroid 138175 is the most probable IFE source.
- Asteroid 138175 has two sensitive regions where the orbit of the asteroid is upstream and the maximum transverse distance away from the ecliptic plane is less than the maximum IFE cross-flow radius.
- All IFEs detected in the sensitive regions are potentially related to the material accompanying the asteroid.

Possible Locations of Co-orbiting Material Accompanying Asteroid 138175

Inside the Sensitive Region

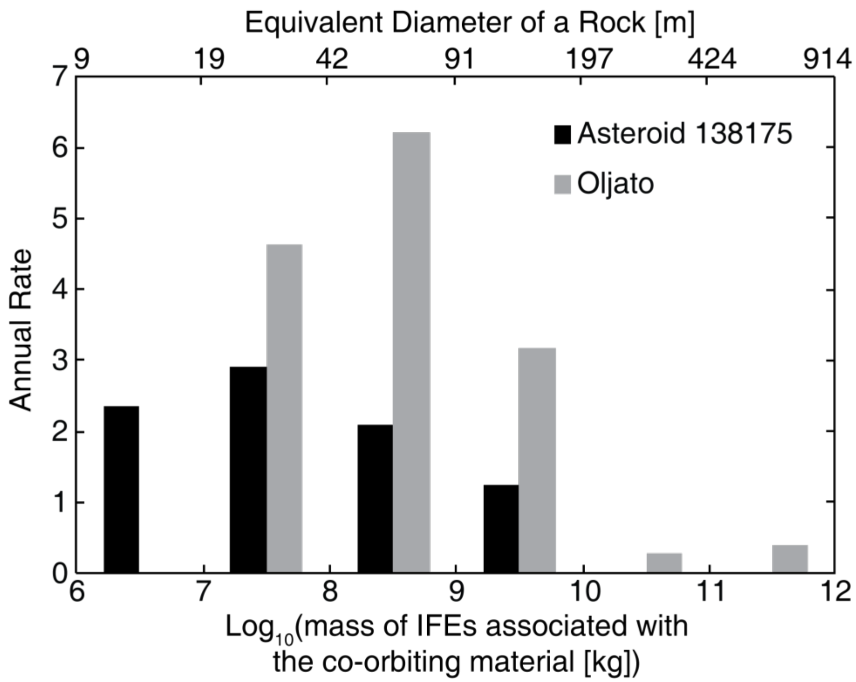


Outside the Sensitive Region



- The correlation in the sensitive region is clear: most IFEs are detected leading the asteroid within 72˚ in longitude.
- Outside the sensitive region, the rate is generally random except for a weak correlation. Such correlation also exists in the Oljato case.
- This may be due to the gravitational spread of the co-orbiting material.

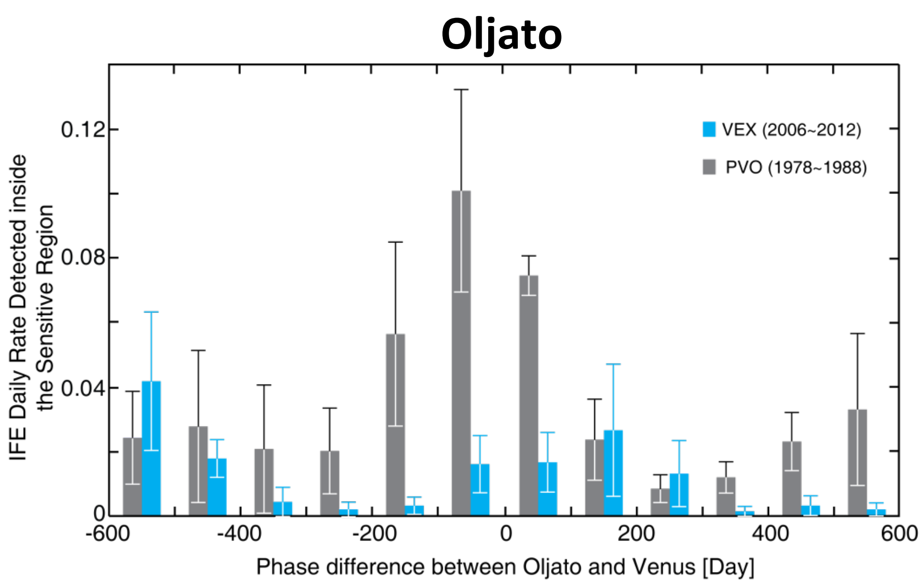
Size of Co-orbiting Material

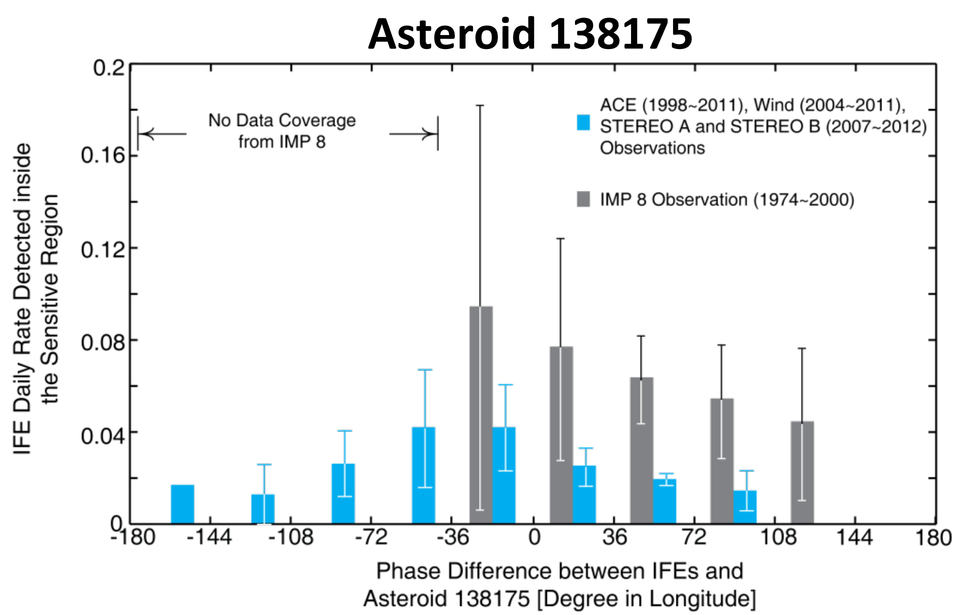


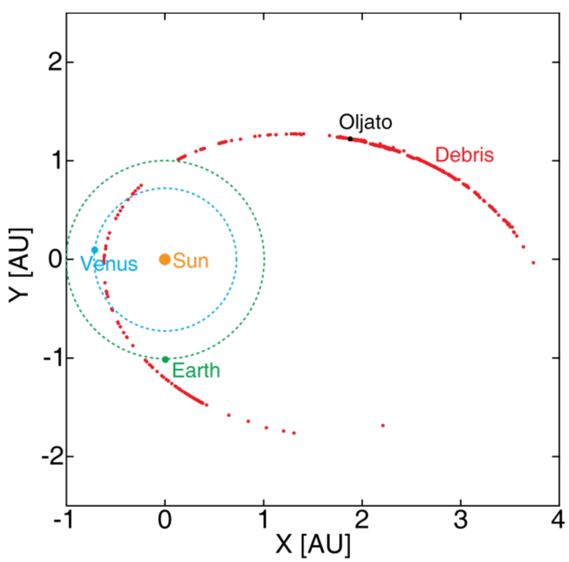
- We can weigh the IFEs by balancing the pressure gradient force with the solar gravity.
- The IFEs have mass from 10^6 to 10^{12}kg. Therefore most of the responsible co-orbiting material is of tens of meters in diameter, too small to detect by traditional optical methods.
- The co-orbitals of Oljato are generally more massive than those of asteroid 138175.
- To create IFEs at the observed rate at 1AU, tens of thousands of objects co-orbit with the asteroid 138175, comprising only ~1% of the original mass of the parent, but greatly increasing the impact hazard from the asteroid.

More details are covered in Poster # 10 *The mass and speed of dust clouds formed By meteoroid-asteroid collisions in solar wind* by C.T. Russell et al.

Temporal Evolution of the Co-orbitals







- Oljato case
  - IFE rate has decreased to be lower than the background
  - Gravitational spread
- Asteroid 138175 case
  - IFE rate has decreased but the distribution does not change
  - Collisions are sufficient in number to reduce the number density of the co-orbitals: the observed decay time scale (~15yr) is consistent with the one calculated from collision models (~43yr) [Grün et al. 1985 & Ceplecha 1992]

Summary

- We can identify interplanetary objects with diameters of tens of meters when they collide with meteoroids.
- Nanoscale dust/gas particles released in the collisions become charged and interact with the solar wind, creating large-scale magnetic structures called interplanetary field enhancements (IFEs).
- We use the IFE occurrence distribution to find material co-orbiting with known NEOs: asteroid 2201 Oljato and asteroid
  - Spatial distribution
  - Size distribution
  - Temporal variation
- While our technique does not identify the location of debris until it is destroyed, it can guide the telescopes where to point.